FINAL REPORT

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ABSTRACT

The response of bimetallic junctions to shock loading was investigated using a new simplified geometry in which the circuit of interest is completed by the impact. Techniques for measuring the 1 millivolt level signals were developed within this geometry with the extensive use of null experiments in which both parts of the junction were of the same material. It was shown that the use of a ferromagnetic material introduces a demagnetization signal that is not well characterized, which puts measurements of thermal E.M.F.s measured in nickel under shock loading conditions in some doubt. Results of experiments involving a nickel 80% chromium 20% alloy indicate that the E.M.F.s involved are anomalously high, in agreement with previous work done elsewhere. The dependence of one-dimensional conditions has not been completely characterized but the indication is that there is indeed some dependence.

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Shock-Induced Electrical Signals from Bimetallic Junctions

1. Introduction

The response of bimetallic junctions to shock loading has been reported by several previous observers to be in qualitative agreement with predicted behavior based on low pressure thermoelectric theory.[1,2,3,4] However, the E.M.F.s observed have generally been anomalously large by as much as a factor of ten and have never been observed to be within 60% of the predicted value. These early efforts to characterize the response of such a junction to the conditions of the shock wave itself and the following high pressure region have led to a general agreement that due to numerous possible causes the junction was not accurately responding to the temperature behind the shock wave. However, in nearly all cases, the E.M.F.s observed were of the appropriate sign and the relative signals between various metallic pairs were in rough correspondence with the respective thermopowers. This correspondence, though not conclusive, indicates that the E.M.F.s are of the same origin and controlled by some of the same factors as the Seebeck effect observed under normal zero pressure conditions.

Although various theroies have been proposed to explain the anomalously high E.M.F.s and moderate success has been obtained in scaling the output with pressure rather than temperature, the experiments conducted prior to the present research are not of sufficient scope or quality to indicate which, if any, such theory is correct. In previous experiments a severe limitation has been impressed by the use of explosive shock loading. This type of experiment limits one to a geometry in which complicated wave interactions with the junction are unavoidable, and electric potential analysis vital to the interpretation is not completely unambiguous.

It has been the intent of the current research to refine the experimental geometry in an attempt to eliminate any complicating interactions which are not well characterized. The use of impact loading in which the circuit of interest is completed by the impact itself, allows a great deal more freedom in designing an experiment devoid of ambiguities and undesirable wave interactions. With this geometry, one is able, in principle, to isolate the response of a bimetallic junction to a simple one-dimensional shock-loaded state.

2. Results

The geometry used in these experiments, though it eliminates various fundamental problems, has led to several technical difficulties which have taken considerable time and effort to resolve. The fact that the circuit is completed by impact makes the experiment vulnerable to induced parasitic signals due to noise sources such as trigger pins and rapid changes in the magnetic field due to flux compression just prior to impact. Techniques have been developed for avoiding and/or eliminating all of the difficulties tending to prohibit the accurate measurement of the .5 to 5 mv signals involved.

Copper Nickel Junctions. In efforts to understand previous work and interpret some interesting preliminary results, an experiment much like that done by O. I. Buzhinskii and S. V. Samylov[4] was undertaken using copper and nickel to make up the junction. The geometry was such that the thermocouple circuit, much like a standard thermocouple, was complete before the shock is initiated. A flier plate impact produced a shock which then traveled through the buffer and the junction, leaving the junction at the high pressure and temperature state. An 11 ± 1 millivolt signal was observed which was, in character, very much like the published records obtained by the Russian investigators. Comparing a linear extrapolation of previous data to the pressure and temperature involved in this experiment would indicate that the observed E.M.F. was about 4 times larger than that observed by Buzhinskii, et al. The E.M.F.s observed here however, were lower than those reported for similar experiments by Jean Crosnier, et al.[5]

The results of this experiment and those previously reported in which a ferromagnetic material is used, are put in doubt by the results of another series of experiments done with nickel. In these experiments, nickel was used as both parts of the bimetallic junction in the simplified geometry in an attempt to obtain a null result. The signal that was observed, however, was a ramp of up to 100 millivolts and random in sign. It was shown through experiments in which the state of magnetization was controlled that the induced currents associated with demagnetization in the shock wave were being coupled to the instrumentation in the null attempts. Though the coupling mechanism between this effect and the measurement of interest is not well understood in the various geometries, including those used in previously reported work, it could have a considerable effect on any measurement involving a ferromagnetic material.

<u>Null Experimentation</u>. Owing to the fact that it is not clear whether all of the signals observed both in our laboratory and in previous work were solely of thermoelectric origin, a great deal of effort has been devoted to obtaining a null result within the simplified geometry of interest. Several experiments were conducted in which the same material was used for both parts of the bimetallic junction. In all of the experiments the signals obtained were zero within the limits

of measurement when known parasitic signals were neglected or eliminated. The one notable exception, previously mentioned, was the set of experiments involving nickel. These null experiments provided a necessary opportunity to discover and eliminate signals which are caused by effects other than those of interest. With the use of all noise suppression techniques developed in this process, null results were obtained with Nichrome V* and copper in which the signals were less than .1 millivolt or about the limit of resolution of the instrumentation.

Nichrome V, Copper Junctions. The series of experiments in which copper and Nichrome V made up the active junction was designed to evaluate the various experimental geometries as well as help to determine and eliminate parasitic signals. In all of these experiments, however, useful data were extracted, though as technique developed greater credibility can be assumed. In the first of these, a geometry very much like that used by Buzhinskii et al. was used and the result was a 1.9 ± .5 millivolt signal at a pressure of 145 kbars. This can be compared to the results of a thermodynamic calculation of the temperature combined with standard low pressure thermoelectric data which would predict a value of .25 millivolts. This result tends to support observations by others of anomalously high signals.

In the remaining experiments of this series, the geometry was changed in steps leading toward the symmetric impact that was the initial goal of this research. In these experiments the signals measured were between 2 mv and .5 mv with the lower signals observed in experiments using the symmetric impact geometry.

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*Nichrome V is a trade mark of Driver-Harris Company, Harrison, New Jersey. Nichrome V is an alloy of 80% nickel and 20% chromium.

The low signal levels involved in this series which result from the relatively low thermoelectric power of Nichrome V make it difficult to draw definitive conclusions as to how these signals compare with predicted values. However, the results tend to support the previous observations of an anomalously high E.M.F.

3. Future Work

Experimentation is ongoing in the areas of perfecting technique and conducting a series of experiments using copper and constantan as the active junction materials. Experimental work is planned to determine the effect of shock loading on the absolute thermopower of a material using a preheated material and/or a porous material.

The underlying theory of the thermoelectric effect is being examined to determine whether or not there are macroscopic sources of signals which result from convection effects in shock waves. These are ignored in the conventional theory.

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4. Publications and Papers

This work was initiated only on November 1, 1975. Much of this first year's work was devoted to technique development. A progress report was given at the winter meeting of the American Physical Society:

"Effects of Shock Compression on Bimetallic Junctions," J. J. Dick and D. D. Bloomquist, Bull. Am. Phys. Soc. II 21, No. 11 (Stanford), 1292 (1 December 1976).

The following papers represent work done under earlier AFOSR sponsorship and not previously reported:

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Other Coupling

Technical discussions with J. Renick of Air Force Weapons Laboratory.

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E.M.F.s measured in nickel under shock loading conditions in some doubt. Results of experiments involving a nickel 80% chromium 20% alloy indicate that the E.M.F.s involved are anomalously high, in agreement with previous work done elsewhere. The dependence of the thermal E.M.F.s generated on the geometry or the assumptions of one-dimensional conditions has not been completely characterized but the indication is that there is indeed some dependence.